Seasonal Diets of Male and Female Double-crested Cormorants from an Oxbow Lake in Arkansas, USA

AMY S. FENECH[1], STEVE E. LOCHMANN[1,3] AND ANDREW A. RADOMSKI[2]

[1]Department of Aquaculture/Fisheries, University of Arkansas at Pine Bluff, 1200 N. University Dr. Mail Slot 4912, Pine Bluff, AR 71601, USA

[2]H. K. Dupree Stuttgart National Aquaculture Research Center, Agriculture Research Service U.S. Department of Agriculture, P.O. Box 1050, Stuttgart, AR 72160, USA

[3]Corresponding author; Internet: slochmann@uaex.edu

Abstract.—Diets were examined and analyzed for 418 wintering Double-crested Cormorants (*Phalacrocorax auritus*) collected from January to mid-April 2001 and October to December 2001 at an oxbow lake in southeast Arkansas. The fish community was also sampled to examine prey availability. Gizzard Shad (*Dorosoma cepedianum*) and Yellow Bass (*Morone mississippiensis*) were the most important species in cormorant diet. Other, less important, cormorant prey species included Channel Catfish (*Ictalurus punctatus*), cyprinids (minnows), and sunfishes (*Lepomis* spp.). Diet varied by season and sex. Cormorants consumed higher proportions of cyprinids and Channel Catfish in the autumn than the remainder of the over-wintering period. In general, females consumed Gizzard Shad more than males, while males consumed Channel Catfish more than females. Neither genders consumed notable amounts of sport fish. Prey size did not differ between the sexes, but did vary by season. These data demonstrate the relative importance of forage and rough fish and the lesser relative importance of sport fish in the diet of cormorants over-wintering on an oxbow lake in southeast Arkansas. *Received 26 November 2003, accepted 17 February 2004.*

Key words.—Arkansas, diet, Double-crested Cormorants, oxbow lake, *Phalacrocorax auritus*, preference, season.

Waterbirds 27(2): 170-176, 2004

Double-crested Cormorant (*Phalacrocorax auritus*; hereafter cormorant) predation can have negative impacts on the aquaculture industry (Schramm *et al.* 1984; Stickley *et al.* 1992; Glahn and Brugger 1995). However, predation impacts on natural fish populations are ambiguous. Some studies indicate that cormorants can negatively affect sport fish populations (Schneider *et al.* 1998; Simmonds *et al.* 2000). Others suggest that cormorants negatively affect fisheries during episodes of unnaturally high fish density, such as stocking events (Modde *et al.* 1996; Derby and Lovvorn 1997; Ross and Johnson 1999). Conversely, some studies (Campo *et al.* 1993; Glahn *et al.* 1996) have found that cormorant diet is composed largely of non-sport fish, such as shad (*Dorosoma* spp.).

Lake Chicot is a valuable recreational, economic, and ecological resource to the town of Lake Village, Arkansas. Lake Chicot historically has supported successful crappie (*Pomoxis* spp.) and Largemouth Bass (*Micropterus salmoides*) fisheries. However, over the past decade, anglers have reported a decline in catchability of adult crappie. Likewise, the Arkansas Game and Fish Commission population abundance estimates for Lake Chicot showed a decrease in the density of adult crappie over the past decade. Their abundance estimates are based on complete sampling of select coves using rotenone, a fish toxicant (Bettoli and Maceina 1996). During this same period, wintering cormorant abundances increased in the Mississippi Delta region (Glahn and Stickley 1995; Jackson and Jackson 1995; Glahn *et al.* 2000). Perhaps due to their behavior, presence, and size, cormorants have become an object of scrutiny for many anglers in this area.

The objectives of this study were to: 1) describe and quantify the seasonal diets of cormorants collected at Lake Chicot and 2) compare use and availability of cormorant prey taxa at Lake Chicot.

STUDY AREA

Lake Chicot is a 2,024-ha oxbow lake of the Mississippi River located in southeast Arkansas (Filipek *et al.* 1991). Lake Chicot has a maximum depth of 9.2 m and a mean depth of 4.2 m. It is a relatively clear (21.5-204 NTU), eutrophic lake (0.032-0.088 mg/L total phosphorus) with a fish community including Largemouth Bass, crappie, sunfish (*Lepomis* spp.), Channel Catfish (*Ictalurus punctatus*), shad, Yellow Bass (*Morone mississippiensis*), Freshwater Drum (*Aplodinotus grunniens*), and several species of cyprinids (minnows; Filipek *et al.* 1991). In addition to serving as a popular fishing location, the lake also supports numerous piscivorous birds, including cormorants, American White Pelican (*Pelicanus erythrorhynchos*), Great Egret (*Ardea alba*), and Great Blue Heron (*A. herodias*).

METHODS

We shot samples of cormorants from the time they arrived at Lake Chicot in January 2001 until their northward migration in April 2001, and when they returned in October 2001 until the end of the year. Collections were categorized seasonally. The winter and spring collections included cormorants shot from 2 January to 21 March and 22 March to 18 April, respectively. Autumn collections were made from 24 October to 21 December. Schramm *et al.* (1984) reported the highest cormorant feeding activity during mid-morning. Therefore, the majority of cormorants were collected during mid-morning to maximize the probability that fish within their esophagus and stomachs were from the lake. "Confidence" decoys, resembling Great Egrets (Flambeau Aquatics Corporation, Middlefield, Ohio, USA), painted black to resemble cormorants, were clamped on an upper limb of a Bald Cypress (*Taxodium distichum*) tree to attract cormorants attempting to rest after feeding. Collectors used 12-gauge shotguns and 3-in (7.62-cm) No. 1 steel shot. Collected birds were weighed (Ohaus remote bench model ES100L balance) immediately to the nearest 0.1 kg. Birds were tagged with an identification number, preserved on ice, and transported to freezer storage. Specimens were frozen until stomachs could be removed. Although cormorants foraged throughout the lake, the specific sampling location was chosen because it is representative of foraging habitat on the lake, cormorants were routinely observed foraging in this area, and because it was used frequently as a resting site. We necessarily assumed that stomach contents of cormorants originated from Lake Chicot, although several aquatic environments that offer adequate forage for cormorants surround the lake, including the Mississippi River and several aquaculture facilities. Collection of birds immediately after they were observed feeding was not possible at Lake Chicot.

During cormorant collections, diurnal electrofishing was used to determine availability of prey taxa on the lake. One autumn, two winter, and three spring collections were made. A Coffelt pulsed DC boat electroshocker model WP-15 (5000-W generator; 25% duty cycle; 60 pulses/sec; 3-6 amps; 400-500 V) was used to collect fish. Three 10-min electrofishing periods were conducted within 400 m of the locations where cormorants were collected. Water depth in this area ranged from 1-3 m. Fish were identified to species and measured to the nearest 1 mm and returned to the lake. Specimens that could not be identified in the field, were placed in a plastic bag, stored on ice, and later identified in a laboratory. We assumed that prey taxa were equally accessible to electrofishing and that prey taxa collected in electrofishing samples were equally available to cormorants. Reynolds (1996) gives a thorough discussion of the factors that influence electrofishing efficiency. Fish species that utilize shoreline habitats, such as centrarchids (bass and sunfish) and cyprinids, may be more vulnerable to electrofishing than species that are pelagic or demersal, such as clupeids (herrings) and ictalurids (catfishes; Reynolds 1996). This will affect availability estimates and the estimated prey preference of cormorants. Although such variables affect efficiency, electrofishing was the best choice of available means to sample the prey taxa at our collection site during different seasons. Because electrofishing was conducted in a relatively open area, fish that were sampled by electrofishing should also have been available to cormorants. This might not have been the case if electrofishing had been conducted in weed beds or around complex cover.

Necropsies on cormorants were conducted according to Carss *et al.* (1997). Fish in the esophagus were removed and placed into a coded bag for later analysis. The stomach was removed, placed into a correspondingly coded bag, and frozen for further analysis. Thawed stomachs were also processed according to Carss *et al.* (1997). Partial and intact prey items that could be identified to family or species were removed. Whole prey items were measured to the nearest mm and weighed to the nearest 0.01 g. The remainder of the stomach contents was retained for reference.

One-way analyses of variance were used to compare average prey sizes by seasons and sex. A relative importance index (George and Hadley 1979) was calculated for each prey taxon. Relative importance was based on frequency of occurrence (the percentage of stomachs containing a specific prey taxon) and the percent composition by number and mass of each prey taxon in the diet. Any one of these three diet characteristics alone can be misleading. For example, percent composition by number can over-emphasize the importance of abundant, but quite small prey items. The relative importance index integrates all three of the diet characteristics and scales the importance of each prey item such that the sum of the relative importances for all prey items is 100. It is derived from the absolute importance index for prey taxon a (AI_a), which is:

AI_a = % frequency of occurrence of prey taxon a + % by number of prey taxon a + % by mass of prey taxon a

We then calculated relative importance for prey item a, (RI_a), as:

$$RI_a = 100^*AI_a / \sum_{p=1}^{n} AI_p$$

where AI_p is the absolute importance of prey taxon p in the diet and n is the number of different prey taxa in the diet.

Diet preference was determined by comparing prey usage to prey availability using the method of Johnson (1980), which is based on ranked data. This method is superior to other similar methods because results are relatively unaffected by decisions regarding what prey items are truly available to a predator. The prey taxa from individual cormorants were ranked by frequency to represent ranked usage for individual birds. The prey taxa from seasonal electrofishing samples were ranked by frequency to represent ranked availability for each season. Proceeding one bird at a time, the rank of availability of each taxa (for the season during which the bird was collected) was subtracted from the rank of usage of that taxa. A multivariate analysis of variance was conducted using the differences between ranked usage and ranked availability for each prey taxa as dependent variables and sex, season, and the interaction between sex and season as independent variables. This allowed testing of the hypotheses that diet varied among seasons and sexes (Johnson 1980). It also allowed testing for significance of an interaction between season and sex.

RESULTS

Seasonal cormorant collections included 140, 195, and 120 cormorants for winter, spring, and autumn, respectively. Of these, 320 (70%) were female and 101 (22%) were male. Due to necrosis of gonadal tissue, 34 cormorants could not be sexed. Autumn-collected cormorants exhibited a 1.6:1 female-to-male ratio. The winter and spring seasons had female-to-male ratios of 5.3:1, and 4.2:1, respectively. Cormorant mass ranged from 1.60 to 3.15 kg.

In all, 917 prey items were recovered and identified from 418 stomachs. Thirty-seven stomachs (8%) were empty. A total of 528 of the identifiable prey items were measurable. For the entire study, prey length ranged from 61 mm to 300 mm and averaged 164 ± 58 mm (SD). The difference in average prey size between sexes was not significant ($F_{1,487}$ = 0.5, n.s.). Prey from male cormorants averaged 159 ± 66 mm and prey from females averaged 163 ± 66 mm in length. Prey items for both sexes were combined and prey size was compared among seasons. There were no differences in prey size between winter and spring. However, significant length differences were found between autumn and the other two seasons ($F_{2,486}$ = 151, $P < 0.001$, Fig. 1). Average prey sizes were 120 ± 54, 191 ± 46, and 193 ± 31 mm for autumn, winter, and spring, respectively.

Cormorant diet was composed mostly of forage and rough fish. Forage fish are non-game species that, as adults, are small enough to be prey of larger species. Rough fish are any fish useless for food, sport or even as bait. Game or sport fish are defined as any fish providing sport for the angler. Gizzard Shad (*Dorosoma cepedianum*) and Yellow Bass generally had the highest relative importance indices (Table 1). The relative importance indices for Gizzard Shad and Yellow Bass were low in male cormorants in the autumn and winter, when Channel Catfish relative importance indices were highest. Cyprinids had higher relative importance indices in both male and female cormorants in the autumn. White Bass (*Morone chrysops*), Largemouth Bass, and White Crappie (*Pomoxis annularis*), while rep-

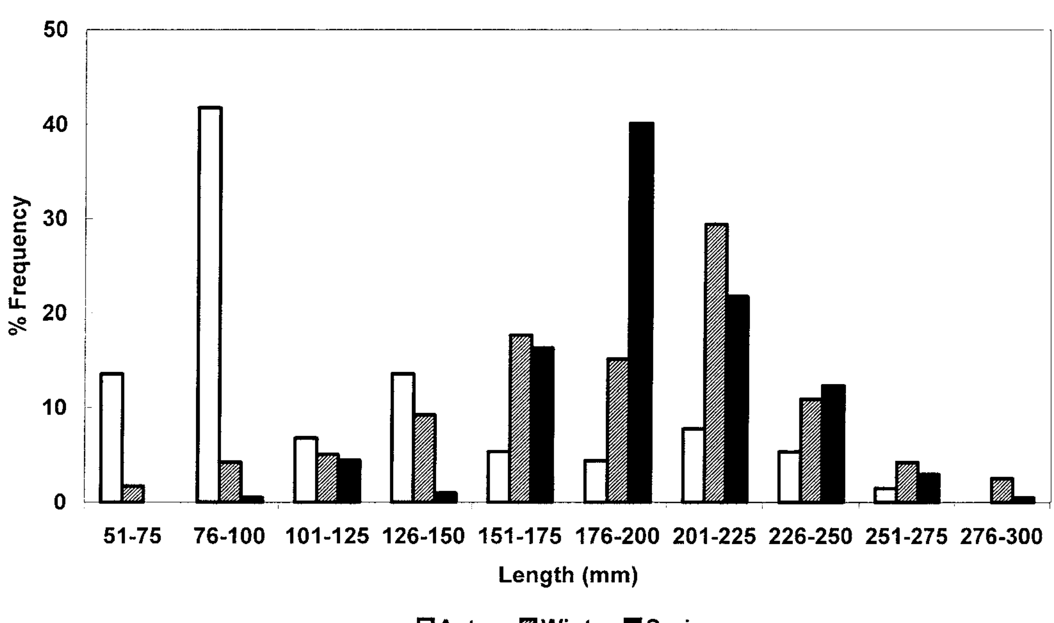

Figure 1. Length frequencies of prey items consumed by Double-crested Cormorants collected on Lake Chicot, Arkansas during the winter, spring, and autumn of 2001.

Table 1. Relative importance indices (SE) of prey items occurring in male (M) and female (F) Double-crested Cormorant diet collected in the autumn, winter, and spring 2001 at Lake Chicot, Arkansas.

	Autumn		Winter		Spring		
Species	M	F	M	F	M	F	Overall
Forage fish							
Gizzard Shad	39 (7)	59 (6)	43 (11)	44 (5)	58 (8)	64 (4)	55 (2)
Cyprinids	19 (6)	12 (4)	0	0	0	0	5 (1)
Inland Silverside	0	4 (2)	0	0	0	0	1 (0)
Rough fish							
Yellow Bass	4 (3)	12 (4)	13 (7)	39 (5)	33 (8)	35 (4)	27 (2)
Freshwater Drum	0	2 (2)	5 (5)	3 (2)	0	0	1 (0)
Sport fish							
White Bass	0	0	7 (6)	0	0	0	0
Channel Catfish	32 (7)	4 (2)	14 (8)	5 (2)	5 (4)	0	6 (1)
White Crappie	0	0	0	0	0	0	0
Largemouth Bass	0	0	7 (6)	0	0	0	0
Sunfishes	6 (4)	7 (3)	11 (7)	8 (3)	4 (3)	1 (1)	5 (1)

resented in the diet, each had relative importance indices less than one.

Eighteen species of fish were collected from Lake Chicot by electrofishing (Table 2). Forage fish made up 20%-30% of the sample in each season. Sport fish represented 58% of fish collected in the autumn. Sport fish and rough fish each accounted for approximately 40% of the fish community during the winter. In spring, 76% of the electrofishing sample was sport fish, while rough fish accounted for less than 1% during that season. Sunfish were the most abundant taxa in the autumn and spring. Yellow Bass were the most abundant taxa in the winter sample.

Cormorant diet varied by season ($F_{2,415}$ = 81.5, P < 0.001) and sex ($F_{1,415}$ = 10.35, P < 0.001), but the interaction was not significant ($F_{2,415}$ = 0.98). Cormorants are opportunistic piscivores, so we hypothesized that the ranks of availability and consumption would be approximately equal. When ranked use exceeded ranked availability, the average difference was positive and cormorants were consuming that diet item more often than expected. We interpret that as a preference for that diet item. There were several trends in the averages of the difference of ranked usage and availability data (Table 3). Specifically, Gizzard Shad were consumed more often than expected in the winter, but not in autumn or spring. Yellow Bass were preferentially consumed in spring, but not in autumn or winter. Channel Catfish were consumed more often than expected in the autumn, but not in the other two seasons. Inland Silversides (*Menidia beryllina*), Largemouth Bass, and sunfish were all consumed less often than expected in all seasons and for both sexes. Interpretation of the data for Freshwater Drum, White Bass, and White Crappie are difficult because they appeared infrequently in both the diets and the electrofishing samples. Female and male cormorant diet differed most with respect to Gizzard Shad, Yellow Bass, and Channel Catfish. Females consumed Gizzard Shad more than males. Even though both sexes did not use Yellow Bass and Channel Catfish in proportion to their availability, males consumed Yellow Bass and Channel Catfish more than females.

DISCUSSION

More female cormorants were collected throughout this study, and the proportions of females were notably higher in the winter and spring. This sex ratio might not be a general representation of the sex ratio of cormorants over-wintering at Lake Chicot, since this was a 1-year study. Similarly, a study by Glahn *et al.* (1995) suggests that females prefer feeding at natural resource areas while males prefer feeding at aquaculture facilities when they are available.

Table 2. Percentage of fish by taxa occurring in electroshocking samples collected in autumn, winter, and spring 2001 at Lake Chicot, Arkansas.

Species	Autumn (N = 174)	Winter (N = 119)	Spring (N = 154)	Total (N = 447)
Forage fish				
Gizzard Shad (*Dorosoma cepedianum*)	3.4	4.2	18.8	8.9
Threadfin Shad (*D. petenense*)	1.1	0.0	0.0	0.4
Red Shiner (*Cyprinella lutrensis*)	0.0	0.0	0.6	0.2
Fathead Minnow (*Pimephales promelas*)	0.0	3.4	0.0	0.9
Inland Silversides (*Menidia beryllina*)	24.7	11.8	3.9	14.1
Rough fish				
Spotted Gar (*Lepisosteus oculatus*)	0.0	0.8	0.0	0.2
Yellow Bass (*Morone mississippiensis*)	11.5	39.5	0.6	15.2
Freshwater Drum (*Aplodinotus grunniens*)	1.1	0.0	0.0	0.4
Sport fish				
Channel Catfish (*Ictalurus punctatus*)	5.7	5.0	7.1	6.0
White Crappie (*Pomoxis annularis*)	0.6	0.0	0.0	0.2
Black Crappie (*P. nigromaculatus*)	0.6	0.8	0.6	0.7
Largemouth Bass (*Micropterus salmoides*)	8.6	11.8	13.0	11.0
Green Sunfish (*Lepomis cyanellus*)	1.1	0.0	0.0	0.4
Warmouth (*L. gulosus*)	0.0	0.0	1.3	0.4
Orangespotted Sunfish (*L. humilis*)	0.6	0.8	3.2	1.6
Bluegill (*L. macrochirus*)	20.1	7.6	20.1	16.8
Longear Sunfish (*L. megalotis*)	19.5	14.3	29.2	21.5
Redear Sunfish (*L. microlophus*)	1.1	0.0	1.3	0.9

The small percentage of empty stomachs (8%) indicated that the collection protocol and time of collections were appropriate to maximizing the number of cormorants collected that had been feeding. Similar studies had greater percentages of empty stomachs ranging from 14% to 18% (Campo *et al.* 1993; Belyea *et al.* 1999; Bur *et al.* 1999).

Prey size tended to be larger at Lake Chicot than at other study areas (Campo *et al.* 1993; Glahn *et al.* 1996; Belyea *et al.* 1999). Prey sizes did not differ between sexes, unlike other studies where males consumed larger prey items than females (Campo *et al.* 1993; Bur *et al.* 1999). However, prey size did differ seasonally, with smaller prey consumed

Table 3. Averages of difference of ranked usage and availability data from Double-crested Cormorant diet and electrofishing samples from Lake Chicot, Arkansas.

	Season			Sex	
Species	Autumn	Winter	Spring	Female	Male
Forage fish					
Gizzard Shad	-1.41	2.11	-0.96	0.30	-0.47
cyprinids	3.92	3.03	-0.05	2.28	2.32
Inland Silversides	-4.97	-2.42	-1.05	-2.80	-2.82
Rough fish					
Yellow Bass	-1.55	-3.80	3.45	-0.41	-0.86
Freshwater Drum	1.53	3.08	3.45	2.70	2.68
Sport fish					
White Bass	3.50	3.16	3.45	3.31	3.43
Channel Catfish	0.94	-0.46	-1.83	-0.85	-0.05
White Crappie	1.50	1.03	1.47	1.32	1.34
Largemouth Bass	-1.00	-2.35	-3.03	-2.18	-2.08
sunfish	-2.48	-3.38	-4.89	-3.68	-3.49

in the autumn, compared to other seasons. Belyea *et al.* (1999) also found seasonal differences of the prey size of cormorants. Prey consumed in the autumn and summer were generally smaller than prey consumed in the spring. In that study, prey size ranged from 75-100 mm for the autumn and summer, but ranged from 75-175 mm during the spring. The smaller autumn prey size in our study was due to the consumption of cyprinids and Inland Silversides. Sizes of Gizzard Shad and Yellow Bass consumed in the autumn were not different than the sizes of those species consumed during other seasons.

Non-sport fish species were the most important prey items of cormorants. These findings agree with other studies that report non-sport fish species as the most important prey items within the cormorant diet (Campo *et al.* 1993; Glahn *et al.* 1996). However, both Campo *et al.* (1993) and Glahn *et al.* (1996) found shad more frequently and in greater numbers in the diet of cormorants compared with this study. Yellow Bass were important in the diet of cormorants collected from Lake Chicot. This has not been previously reported in the literature.

Sport fish, such as sunfish and Channel Catfish, were relatively unimportant in our study. Only two Largemouth Bass, one White Bass, and one White Crappie were found. Campo *et al.* (1993) studied reservoirs in Texas and identified similar numbers of sunfish (8% by number) in cormorant diet. However, sunfish accounted for a greater proportion of prey taxa by mass (15%) in Campo *et al.* (1993) than in this study (3%). These differences might be attributed to the importance of Yellow Bass in diets of cormorants in Lake Chicot.

The percentages of three species varied between seasons by more than 10%. Gizzard Shad, Inland Silversides, and Yellow Bass are schooling species, so some of the differences between seasons might be related to sampling variability. However, fish can leave the open part of the lake and move to bayous or creek channels. Yellow Bass, for example, are known to move into tributary areas during spring spawning. Spring was the season in which Yellow Bass composed the smallest percentage of the fish taxa sampled by electroshocking.

Within their summer range, cormorants fed on the most abundant fish available in a foraging location (Craven and Lev 1985). Summer diet tends to consist of abundant, soft-bodied, schooling fish (Bur *et al.* 1999). Cormorant diets in other seasons are likely to be similar. Although Yellow Bass are not considered soft-bodied, they are a prevalent species in Lake Chicot. They exhibit schooling behavior (Robison and Buchanan 1988). Therefore, the importance of schooling fish, such as shad and Yellow Bass, in the diet of cormorants collected at Lake Chicot is consistent with these findings. However, Channel Catfish are not known as a schooling species. Gizzard Shad, Yellow Bass, and Channel Catfish were present in diets and electrofishing samples in all seasons. It is not apparent why the importance and usage of those three species varied with season.

We found differences in the diet of male and female cormorants. Taxa consumed by males and females in our study agree with the findings of Campo *et al.* (1993). Males in our study consumed a higher proportion of Channel Catfish than females. However, unlike Campo *et al.* (1993), this did not appear to affect the differences in prey sizes consumed between sexes on Lake Chicot. Campo *et al.* (1993) and Bur *et al.* (1999) found no differences between sexes in the number of prey items consumed per bird, which is similar to the findings of this study.

This study found seasonal and sex differences in diets of cormorants. Therefore, investigations of the influence of over-wintering cormorants on fish communities should include samples from all seasons. The sex ratio of over-wintering cormorants should also be considered. There was no evidence of a link between decline of crappie and crappie consumption by cormorants over-wintering at Lake Chicot. However, water bodies that do not contain abundant forage or rough fish populations may encounter greater losses of sport fish. In Lake Chicot, the high abundances of Gizzard Shad and Yellow Bass led to relatively important roles for Gizzard Shad and Yellow Bass in the diet of cormorants.

ACKNOWLEDGMENTS

We thank the Arkansas Game and Fish Commission, USDA-ARS, H. K. Dupree Stuttgart National Aquaculture Research Center, and the University of Arkansas at Pine Bluff Aquaculture and Fisheries Center for funding this project. We thank several anonymous reviewers for providing comments during the preparation of the manuscript. We also are grateful to all the technicians, graduate students, and undergraduate students for their assistance in the collection of cormorants, particularly Christopher L. Racey who participated in the majority of the collections.

LITERATURE CITED

Belyea, G. Y., S. L. Maruca, J. S. Diana, P. J. Schneeberger, S. J. Scott, R. D. Clark, Jr., J. P. Ludwig and C. L. Summer. 1999. Impact of double-crested cormorant predation on the yellow perch population in the Les Cheneaux Islands of Michigan. Pages 47-59 *in* M. E. Tobin, Technical coordinator. Symposium on Double-crested Cormorants: Population Status and Management Issues in the Midwest. United States Department of Agriculture Technical Bulletin 1879.

Bettoli, P. W. and M. J. Maceina. 1996. Sampling with toxicants. Pages 303-333 *in* B. R. Murphy and D. W. Willis, Eds. Fisheries Techniques 2nd Edition. American Fisheries Society. Bethesda, MD.

Bur, M. T., S. L. Tinnirello, C. D. Lovell and J. T. Tyson. 1999. Diet of the double-crested cormorant in western Lake Erie. Pages 73-85 *in* M. E. Tobin, Technical coordinator. Symposium on Double-crested Cormorants: Population Status and Management Issues in the Midwest. United States Department of Agriculture Technical Bulletin 1879.

Campo, J. J., B. C. Thompson, J. C. Barron, R. C. Telfair II, P. D. Durocher and S. Gutreuter. 1993. Diet of double-crested cormorants wintering in Texas. Journal of Field Ornithology 64: 135-144.

Carss, D. N., R. M. Bevan, A. Bonetti, G. Cherubini, J. Davies, D. Doherty, A. El Hili, M. J. Feltham, N. Grade, J. P. Granadeiro, D. Gremillet, J. Gromadzka, Y. N. R. A. Harari, T. Holden, T. Keller, G. Lariccia, R. Mantovani, T. K. McCarthy, M. Mellin, T. Menke, I. Mirowska-Ibron, W. Muller, P. Musil, T. Nazirides, W. Suter, J. F. G. Trauttmansdorff, S. Volponi and B. Wilson. 1997. Techniques for assessing cormorant diet and food intake: towards a consensus view. Supplemento Ricerche di Biologia della Selvaggina 26: 197-230.

Craven, S. R. and E. Lev. 1985. Double-crested cormorant damage to a commercial fishery in the Apostle Islands, Wisconsin. Pages 14-24 *in* P. T. Bromley, Ed. Proceedings of the Second Eastern Wildlife Damage Control Conference.

Derby, C. E. and J. R. Lovvorn. 1997. Predation on fish by cormorants and pelicans in a cold-water river: a field and modeling study. Canadian Journal of Fisheries and Aquatic Sciences 54: 1480-1493.

Filipek, S. P., J. D. Ellis, W. J. Smith, D. R. Johnson, W. M. Bivin and L. L. Rider. 1991. The effect of the Lake Chicot renovation project on the fishery of a Mississippi River oxbow lake. Proceedings of the Annual Conference of Southeast Association of Fish and Wildlife Agencies 45: 293-306.

George, E. L. and W. F. Hadley. 1979. Food and habitat partitioning between rock bass (*Ambloplites rupestris*) and smallmouth bass (*Micropterus dolomieui*) young of the year. Transactions of the American Fisheries Society 108: 253-261.

Glahn, J. F. and K. E. Brugger. 1995. The impact of double-crested cormorants on the Mississippi delta catfish industry: a bioenergetics model. Colonial Waterbirds 18: 168-175.

Glahn, J. F., P. J. Dixson, G. A. Littauer and R. B. McCoy. 1995. Food habits of double-crested cormorants wintering in the delta region of Mississippi. Colonial Waterbirds 18: 158-167.

Glahn, J. F., J. B. Harrel and C. Vyles. 1996. The diet of wintering double-crested cormorants feeding at lakes in the southeastern United States. Colonial Waterbirds 19: 73-81.

Glahn, J. F., D. S. Reinhold and C. A. Sloan. 2000. Recent population trends of double-crested cormorants wintering in the delta region of Mississippi: responses to roost dispersal and removal under a recent depredation order. Waterbirds 23: 38-44.

Glahn, J. F. and A. R. Stickley, Jr. 1995. Wintering double-crested cormorants in the delta region of Mississippi: population levels and their impact on the catfish industry. Colonial Waterbirds 18: 137-142.

Jackson, J. A. and B. J. S. Jackson. 1995. The double-crested cormorant in the south-central United States: habitat and population changes of a feathered pariah. Colonial Waterbirds 18: 118-130.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61: 65-71.

Modde, T., A. F. Wasowicz and D. K. Hepworth. 1996. Cormorant and grebe predation on rainbow trout stocked in a southern Utah reservoir. North American Journal of Fisheries Management 16: 388-394.

Reynolds, J. B. 1996. Electrofishing. Pages 221-251 *in* B. R. Murphey and D. W. Willis, Eds. Fisheries Techniques, Second Edition. American Fisheries Society. Bethesda, MD.

Robison, H. W. and T. M. Buchanan. 1988. Fishes of Arkansas. The University of Arkansas Press, Fayetteville.

Ross, R. M. and J. H. Johnson. 1999. Fish losses to double-crested cormorants in eastern Lake Ontario, 1992-97. Pages 61-70 *in* M. E. Tobin, Technical coordinator. Symposium on double-crested cormorants: population status and management issues in the Midwest. United States Department of Agriculture Technical Bulletin 1879.

Schramm, H. L., Jr., B. French and M. Ednoff. 1984. Depredation of channel catfish by Florida double-crested cormorants. Progressive Fish Culturist 46: 41-43.

Schneider, C. P., A. Schiavone, Jr., T. H. Eckert, R. D. McCullough, B. F. Lantry, D. W. Einhouse, J. R. Chrisman, C. M. Adams, J. H. Johnson and R. M. Ross. 1998. Double-crested cormorant predation on smallmouth bass and other warm water fishes of the eastern basin of Lake Ontario: overview and summary. Pages 1-6 *in* New York State Department of Environmental Conservation Special Report, 15 Dec. 1998.

Simmonds, R. L., Jr., A. V. Zale and D. M. Leslie, Jr. 2000. Modeled effects of double-crested cormorant predation on simulated reservoir sport and forage fish populations in Oklahoma. North American Journal of Fisheries Management 20: 180-191.

Stickley, A. R., Jr., G. L. Warrick and J. F. Glahn. 1992. Impact of double-crested cormorant depredation on channel catfish farms. Journal of the World Aquaculture Society 23: 192-199.